Canada Alberta

FOREST RESOURCE DEVELOPMENT AGREEMENT
ENTENTE SUR LA MISE EN VALEUR DES RESSOURCES FORESTIERES

Canada Alberta

The Canada–Alberta Forest Resource Development Agreement is a subsidiary agreement of the Canada–Alberta Economic and Regional Development Agreement, which provides coordination and cooperation between the governments of Alberta and Canada in areas of Alberta's economic development.

The Canada–Alberta Forest Resource Development Agreement is funded equally by the governments of Canada and Alberta, from April 1, 1984, to March 31, 1989.

Its primary objectives are to ensure the long-term availability of timber supplies; to optimize timber uses; and to contribute to the growth and diversification of Alberta's economy.

The Agreement comprises three programs: Reforestation; Applied research, technology transfer and opportunity identification; and Public information, evaluation and administration. These programs are managed by a joint Directorate and are implemented by Forestry Canada and the Alberta Forest Service.

L'Entente Canada–Alberta sur la mise en valeur des ressources forestières est auxiliaire à l'Entente Canada–Alberta sur le développement économique et régional, qui vise à assurer la coordination et la coopération des deux gouvernements relativement au développement économique de l'Alberta.

L'Entente Canada–Alberta sur la mise en valeur des ressources forestières est financée à parts égales par les gouvernements du Canada et de l'Alberta, et a cours du 1er avril 1984 au 31 mars 1989.

Ses objectifs principaux sont assurer la disponibilité à long terme de réserves de bois; optimiser leur utilisation; et contribuer à la croissance et la diversification de l'économie de la province.

L'Entente comprend trois programmes: Reboisement; Recherche appliquée, transferts de connaissances techniques et relevé des occasions; et Information, évaluation et administration. Ces programmes sont gérés par un Bureau de direction conjoint, et mis en oeuvre par Forêts Canada et le Service forestier de l'Alberta.

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DECAY LEVELS IN MATURE ASPEN STANDS Whitecourt, Alberta

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This is a joint publication of Forestry Canada and the Alberta Forest Service pursuant to the Canada-Alberta Forest Resource Development Agreement

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Project # 1467-72

DISCLAIMER

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Catalogue No.: FO 42-91/73-1989E
ISBN: 0-662-17144-6

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ABSTRACT

A detailed cull survey was undertaken in mature and overmature hardwood stands in two management units of the Whitecourt Forest. Three categories of decay (advanced, incipient and stain) were identified and measured on 985 aspen and poplar trees. Total defect and percent defect by tree were then calculated. Analysis of variance indicated no significant difference existed between percent decay levels and the independent variables tested (dbh, height, site index, stump age, photo-interpreted stand age, external decay indicators, cull suspect class). Dbh, tree height and stump age were found to be significant variables for estimating the absolute volume of defect. Stump age could prove useful in estimating some levels of decay. However, due to the multi-age structure of the sampled stands, it is difficult to determine an average stand age. Results indicated that tree size is of greater value in estimating decay than age, hence regression equations were developed to predict defect volumes using a combination of tree dbh and height. Using this approach, estimates of defect are not tied directly to a forest management inventory; rather, stand merchantability is determined from an operational cruise assessment.

On an individual tree basis, advanced decay generally averages 7%, advanced plus incipient, 10%, and total decay (including stain) 39% of total gross tree volume. Total stand defect volume was then calculated using the plot data collected from the study. Based on its percent defect, each stand was classified as to its potential use (chips, pulp, or replace). All sampled stands were found to be useable for chip production. The use of overmature stands for pulp production is restricted by the large stain component which results in increased processing costs rather than a loss of volume to the facility.

ACKNOWLEDGEMENTS

This study was conducted under funding supplied by the Canada-Alberta Forest Resource Development Agreement. Supervision of field activities and preparation of data were carried out by C. Thacker and T. Kuzma of the Whitecourt Forest.

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1 INTRODUCTION

Populus tremuloides Michx. (trembling aspen) and Populus balsamifera L. (balsam poplar) occur in extensive stands in Alberta. Together the two species constitute 44% of the volume of provincial forests according to current inventory figures.

Until recently, the Populus species were not economically attractive. The result was that these species were not inventoried in detail, and few surveys were conducted to ascertain levels of internal decay.

Current commercial interest in Populus species is centred upon their use for oriented strand board (OSB) and chemi-thermal-mechanical pulp (CTMP). Both of those processes are sensitive to the level of decay present, although OSB plants are capable of utilizing wood with a higher level of decay. Lack of knowledge about decay levels has limited commercial exploitation of the species.

In 1985 the establishment of a CTMP mill at Whitecourt was under consideration. Woodbridge, Reed and Associates, the Consultant hired to assess the feasibility of a mill, determined that the mill could tolerate a maximum of 20% combined stain and decay in its wood supply and still be commercially viable. The Consultant further recommended that harvesting be concentrated in stands of 60-80 years where defect levels were expected to be within tolerable levels and trees large enough to make logging profitable.

The incidence and extent of decay and stain in Populus stands is difficult to estimate due to its extreme variability and the lack of reliable external indicators. Unlike the coniferous species, high levels of decay can develop quickly and at a relatively early age. Too little decay sampling of older stands has been conducted to define net volume trends with age.

In support of the mill feasibility study, a cull survey was conducted in 1985 to evaluate the Populus 60-80 year and 40-60 year age classes, the latter being included to obtain an indication of wood supply quality the mill would utilize in the second rotation. The feasibility study supported mill construction, which is now taking place.

Close to half of the standing deciduous volume in the Whitecourt area exceeds eighty years of age according to the Phase 3 Forest Inventory. This meant that further surveys were necessary to quantify decay levels in older stands to provide a basis for managing that resource. As previous research has not shown that Populus decay varies significantly between geographic regions, survey results could potentially be applied to older stands throughout Alberta.

Funding for a cull survey to obtain information on aspen decay trends in older stands was provided by the Canada Alberta Forest Resource Development Agreement. Field sampling was carried out during the period of October 12, 1987 to March 31, 1988. This report describes how the project was conducted and the results obtained.

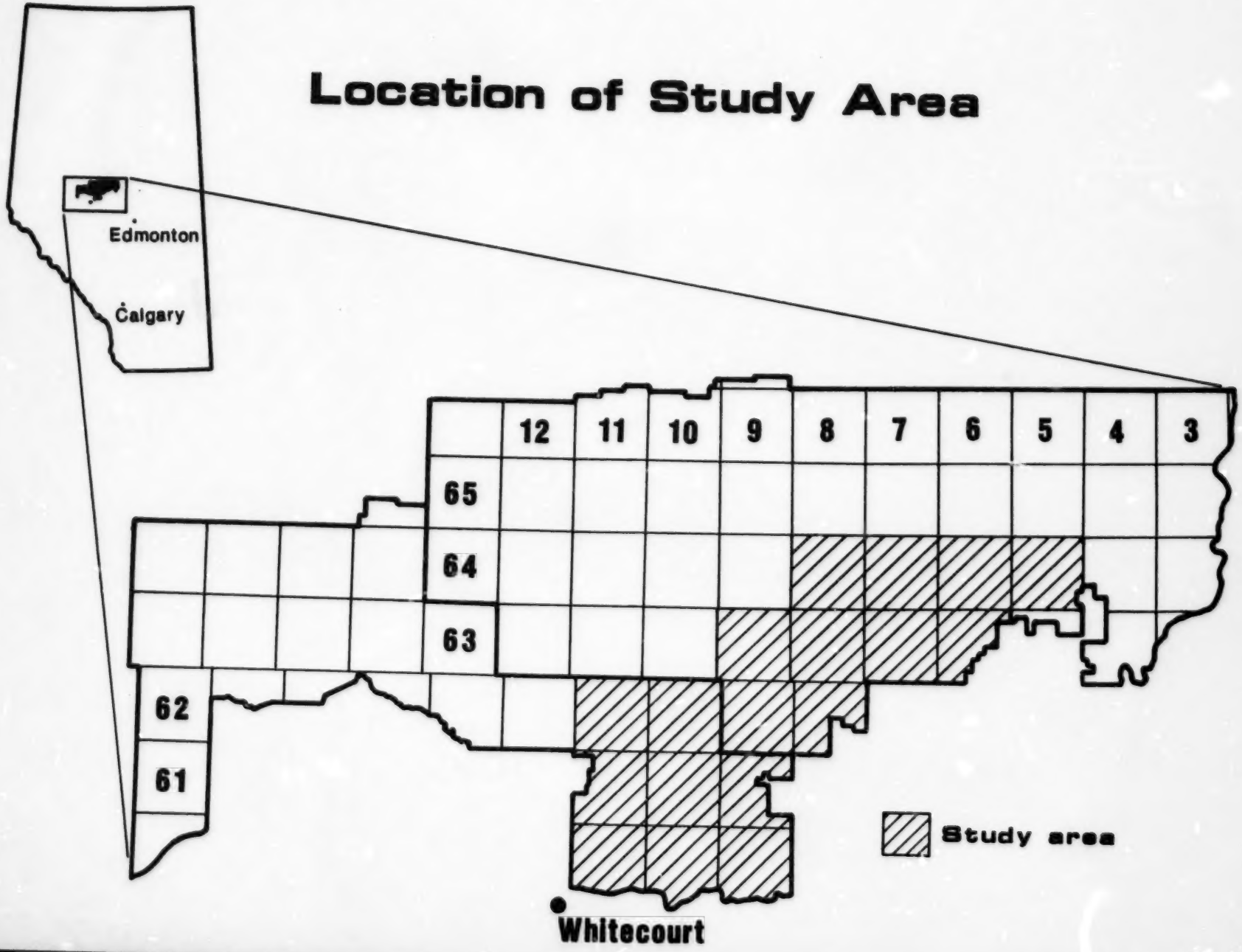
2 DESCRIPTION OF THE STUDY AREA

Aspen field sampling was conducted in forest management units (FMUs) W3 and W4 which are located northeast of Whitecourt, Alberta (Figure 1). In area these constitute approximately 648 square miles.

The forest in FMUs W3 and W4 is within the Boreal Forest Region classified as Section B18a by Rowe (1972). He describes the characteristic forest association of the rolling morainic deposits on the well-drained uplands as a varying mixture of trembling aspen and balsam poplar, white birch (Betula payrifera Marsh.), white spruce (Picea glanca (Moench.) Voss) and balsam fir (Abies balsamea (L.) Mill), the latter two species being especially prominent in older stands. The cover type of greatest areal extent is trembling aspen. Jack pine (Pinus banksiana Lamb.) appears on the drier till soils, and mixes with black spruce (Picea mariana (Mill.) B.S.P.) on the plateau-like tops of the higher hills. Lower positions and upper water catchment areas develop black spruce and tamarack (Larix laricina (Du Roi) K. Koch) muskeg. Many of the hardwood stands have a white spruce understorey. Almost all stands are thought to be even-aged and of fire origin (Anon. 1984).

These FMUs were selected for sampling because of their close proximity to Whitecourt, creating a logical initial supply area for the Millar Western Industries Ltd. CTMP mill now under construction. Blue Ridge Lumber is also harvesting some mixedwood (hardwood/softwood) stands in the area on an experimental basis.

Figure 1


Location of Study Area
Edmonton
Calgary
12
11
10
9
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5
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3
65
64
63
62
61
Study area
Whitecourt

3 METHODS

3.1 Sampling Design

Sample design followed that used during the 1985 aspen cull survey to ensure that data from the two projects could be combined for statistical purposes. Numbers of trees sampled was determined by the resources available for the project, namely two, (later three) two-person field crews and one person employed to determine tree ages and to measure tree and cull volumes. The Alberta Forest Service also contributed a crew supervisor, administrative services and other assistance.

Stands to be sampled were selected from Phase 3 Forest Inventory records according to species composition and age. Three age classes were selected for sampling: 80-100 years, 100-120 years and over 120 years. One third of the 100 stands to be sampled were to come from each age class, and, within each age class, one third of the stands were chosen from each of three covertypes: pure aspen, aspen stands with less than twenty percent softwood, and aspen/softwood stands in which aspen predominates.

Inventory records provided a list of all of the stands that met selection criteria. From that list a ratio (by township) was derived by dividing the number of available stands in each age/cover type combination by the total number of stands meeting the selection criteria. This ratio was used to determine the number of stands to randomly select from each township. Once selection was completed the sample stands were marked on 1:50 000 Phase 3 maps (Anon 1985b).

Plot location in each sample stand followed that used during the 1985 survey. Three plots were randomly located in each target stand with the aid of a grid overlay. Plots had to be 100 m from stand boundaries and from each other. Plot locations were recorded on 1:15 000 Phase 3 maps prior to commencement of field work to reduce field bias.

3.2 Field Procedures

Prior to field sampling, an attempt was made by the project supervisor to visit each candidate stand to assure that it met sampling criteria ie. an aspen or aspen-conifer stand existed at the location shown on the Phase 3 map. Stands also had to contain at least 50 m^3/ha of aspen volume (15/11 stump dob/top dib utilization). Some stands from which the conifer component had been recently removed by logging were included in the samples to represent aspen in mixed wood configurations as well as to reduce access costs.

In each confirmed sample stand, two-person crews used Silva hand compasses and metric steel chains to locate plot centers. A BAF 3 prism was used to select plot trees starting with the tree closest to the chain and proceeding in a clockwise direction. Each plot had to contain three live aspen trees 13.6 cm dbh or larger, or two such trees plus a live balsam poplar greater than 13.6 cm dbh. If that criterion was not met the plot centre was moved 50 m back from whence the crew came or forward in the direction they had been headed.

The species, crown class and dbhob (diameter outside bark at breast height) of each "in" tree were recorded along with any likely visible decay indicators. The defect description included defect type, location, and severity or development stage (see Appendix 1). The height of one codominant tree representative of the plot trees was also recorded. In two of the three plots the first three "in" Populus trees larger than 15m stump dob were felled, sectioned and measured according to standard Alberta Forest Service (AFS) procedures (Anon. 1986).

Two-inch-thick sections or cookies were cut from the end of each log for later age determination and cull measurement.

3.3 Age and Cull Determination

A small laboratory was established in the Whitecourt AFS warehouse. There, each cookie was planed and sanded. Ring counts were made with the aid of a ten power magnifying glass. One person was employed to determine the age of each sectioned tree and to calculate the volume of internal cull. Three categories were recognized:

Advanced Rot: Wood is perceptibly soft and punky, normally with "black zones" indicating concentrations of break-down products.

Incipient Decay: This is an intermediate stage of decay where the cell walls making up the wood are beginning to break down and wood toughness or hardness is reduced. It can be operationally defined as a change in texture (relative to that of clear wood) apparent when the wood surface is scraped with a pocket knife or similar object.

Stain: Wood is discolored, but does not demonstrate any of the above symptoms of decay.

3.4 Method of Analysis

Data collected for this survey was keypunched and edited. Statistical analysis was completed using the Statistical Package for the Social Sciences (SPSS).

Analysis of the data was carried out in several steps. First, graphical procedures were used to visually determine if any trends existed between decay levels and tree or stand characteristics. Analysis of variance and Scheffe range tests were then applied to variables that appeared to have some relationship to defect volume.

4 RESULTS

Figure 2 displays scatterplots of advanced+incipient+stain volumes as a function of diameter at breast height, total height, site index, stump age, photo-interpreted stand age, external decay indicator and cull suspect class. Figure 3 shows scatterplots of percent advanced+incipient+stain estimates based on the same variables as listed above. Scatterplots of advanced decay and advanced+incipient decay area included in Appendix 2.

Table 1 shows the correlations (r^2) between numerous independent variables and the three levels of internal defect. These correlations are presented for both the actual defect and the defect volume expressed as a percent of the gross tree volume as the dependent variables. Table 1 indicates that a greater number of variables were found to be significant when predicting the actual volume of defect rather than the percent defect.

Analysis of variance was conducted to determine the statistical significance of the independent variables and interactions of variables for the estimation of both total decay volume and percent decay. Based on the ANOVA results, multiple comparison (range) tests were performed on significant variables. Range tests indicate significant differences of groups within a single variable. For example, if crown class was a significant variable, a range test could tell us which classes (dominant, codominant, intermediate or suppressed) were different from each other. The results of the Scheffe multiple comparison tests are presented in Tables 2 and 3.

4.1 Species

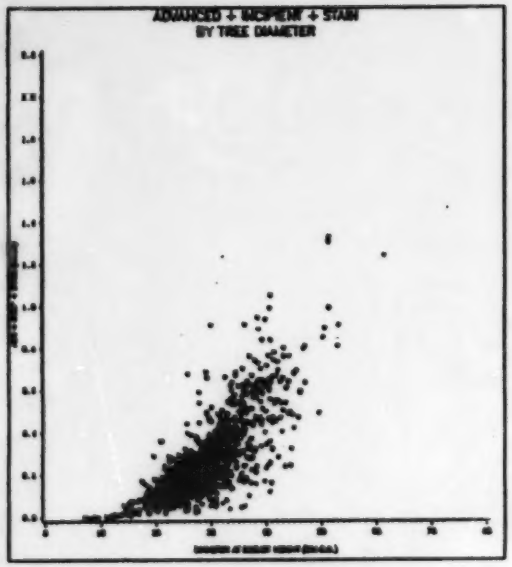
Differences in decay estimates between the two Populus species were found to be statistically significant. This was due to an imbalance in sample sizes between the two species. Only 57 poplar trees were sectioned from the entire data base of 985 trees. The distribution of decay volumes by species and ten-year stump age class is shown in Figures 4a and 4b.

As poplar formed such a small component of the study, further tests applied to the data base did not differentiate between species.

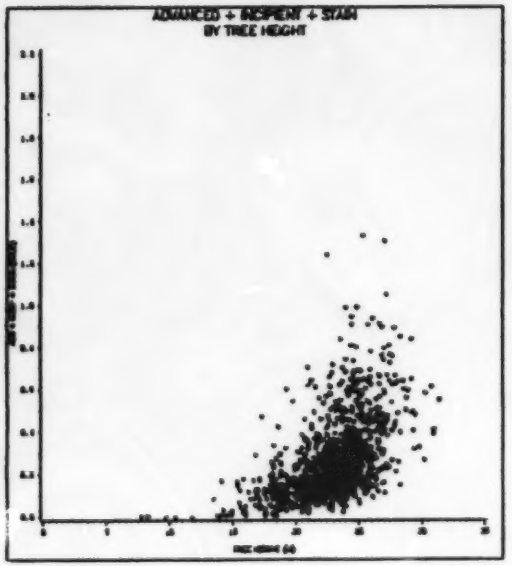
4.2 Cover Group

Cover group defines the species mix in each stand. Two cover groups were recognized: pure deciduous stands (less than 10% conifer by crown closure), and mixedwood stands (coniferous component can be from 11-50% of the stand's estimated crown closure).

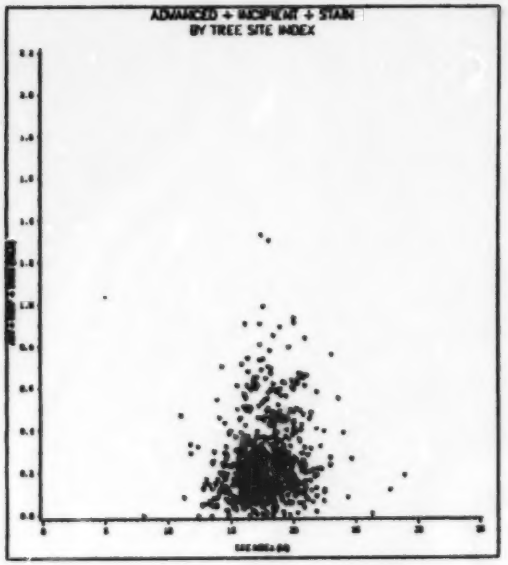
No significant differences were noted in decay levels of trees occurring in pure hardwood versus mixedwood configurations. A graph of average decay values is shown in Figures 5a and 5b. The poor relationship of decay level to cover group is likely due to the wide variability in decay estimates on a tree-by-tree basis, and the imbalance in sample sizes between the two groups.



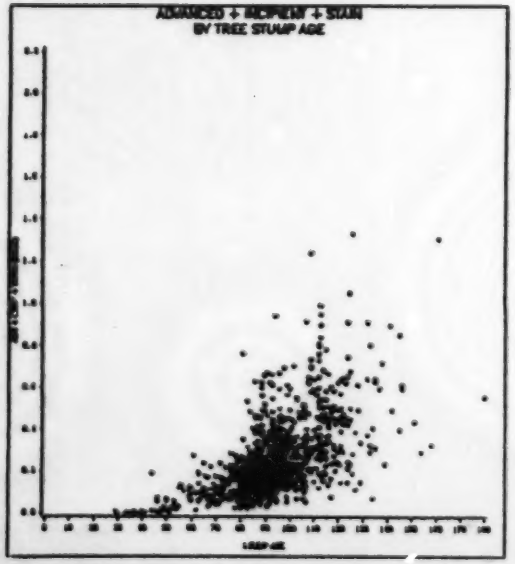
a) Tree diameter at breast height (cm o.b.)



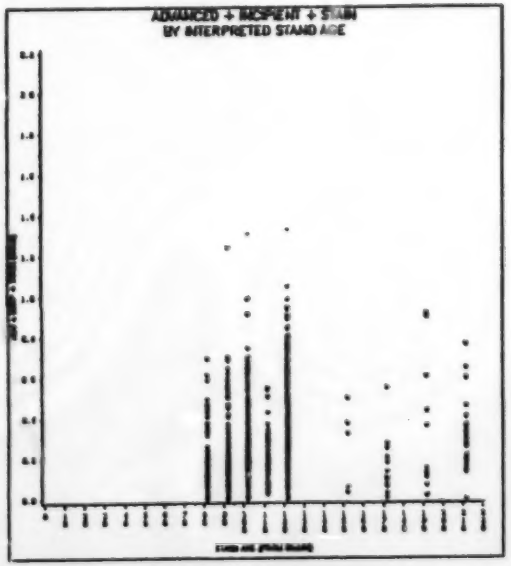
b) Tree height (m)



c) Tree site index (m. at 50 years b.h. age)



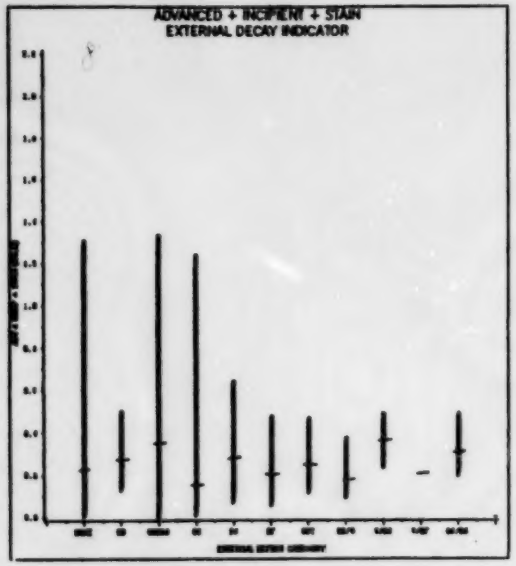
d) Tree stump age (years)



e) Photointerpreted stand age (10 year classes)

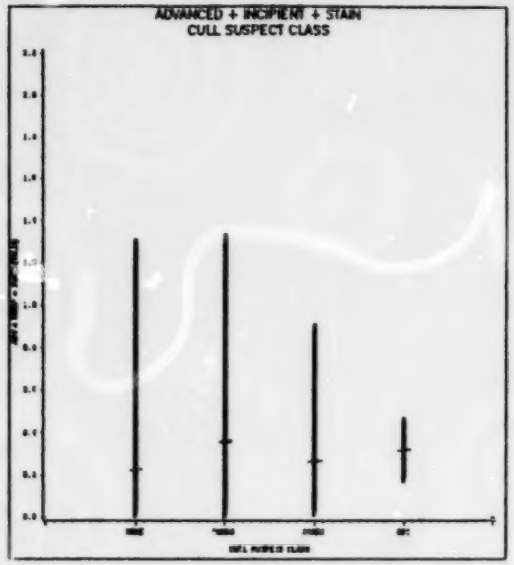
Figure 2

Scatterplots of Total Defect



f) External decay indicator

NONE - No indicator
DB - Discolored Bark
CONKS - Conks or cankers
OS - Open scar
BS - Branch stubs
DF - Dead foliage
OBT - Old broken top
DB/C - Discolored bark/Conks
C/BS - Conks/Branch stubs
C/DF - Conks/Dead foliage
OS/DF - Open scars/Dead foliage



g) Cull suspect class

NONE - No indicator
CONKS - Conks or cankers
SCARS - Open scars
OBT - Old broken top

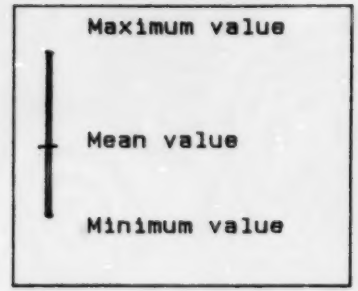
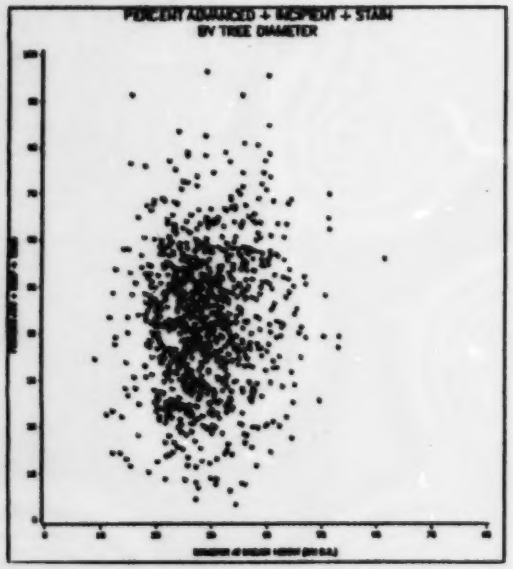
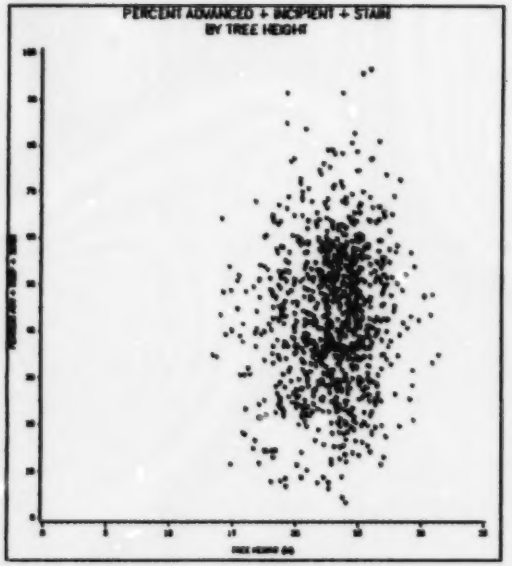


Figure 2 cont'd

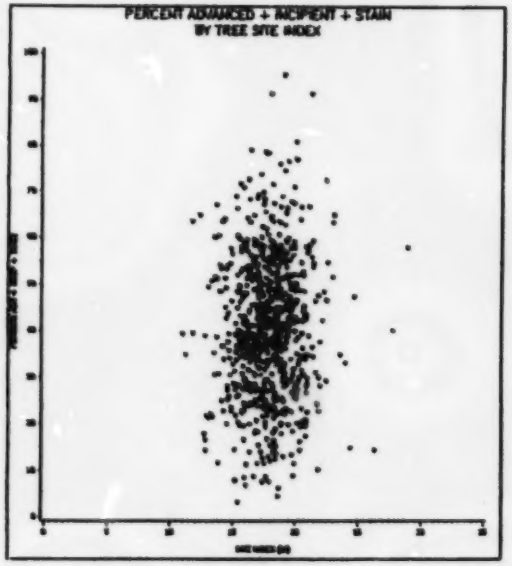
Scatterplots of Total Defect



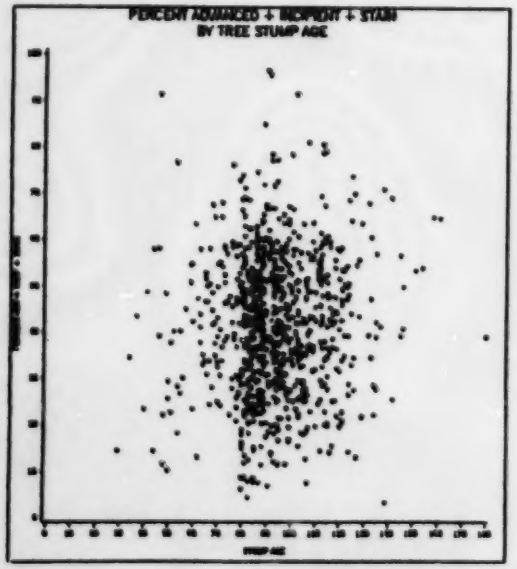
a) Tree diameter at breast height (cm o.b.)



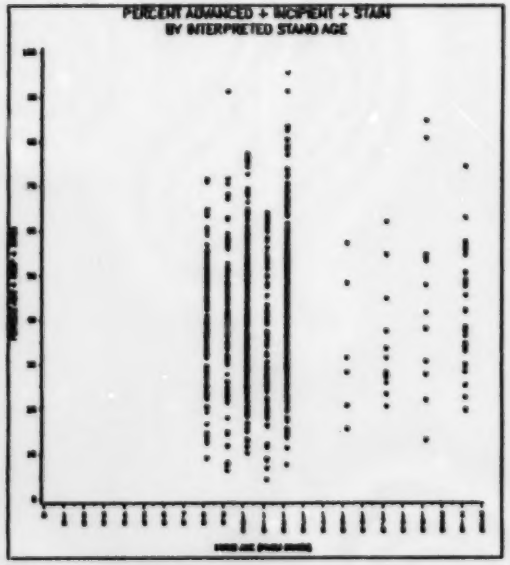
b) Tree height (m)



c) Tree site index (m. at 50 years b.h. age)



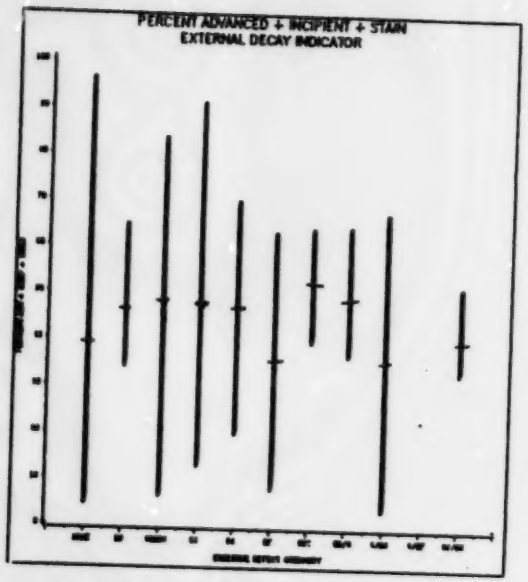
d) Tree stump age (years)



e) Photointerpreted stand age (10 year classes)

Figure 3

Scatterplots of Percent Total Defect



f) External decay indicator

NONE - No indicator
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OS - Open scar
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OBT - Old broken top
DB/C - Discolored bark/Conks
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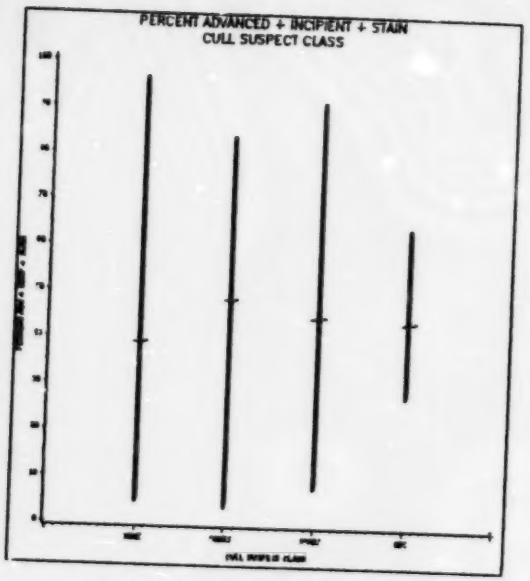
C/DF - Conks/Dead foliage
OS/DF - Open scars/Dead foliage



g) Cull suspect class

NONE - No indicator
CONKS - Conks or cankers
SCARS - Open scars
OBT - Old broken top

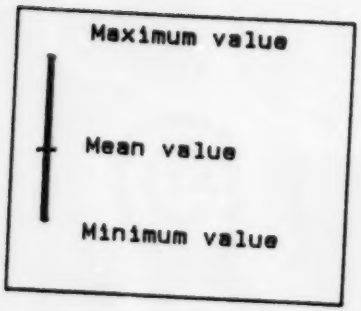


Figure 3 cont'd

Scatterplots of Percent Total Defect

TABLE 1

CORRELATIONS OF DECAY LEVEL WITH TREE AND STAND VARIABLES

	Actual Volume			Percent		
	Adv	Adv+Incip	Adv+Incip+Stain	Adv	Adv+Incip	Adv+Incip+Stain
Individual Tree Variables						
Height	.236	.284	.546	.061	.029	.076
Dbh	.377	.447	.773	.104	.059	.097
External Defect Type	.067	.069	.088	.069	.066	.087
External Defect Location	.113	.143	.141	.112	.135	.184
External Defect Severity	.178	.229	.205	.178	.223	.241
Cull Class	.159	.200	.197	.154	.187	.212
Stump Age	.272	.315	.596	.050	.020	.074
Gross Volume	.307	.374	.715	.027	-.018	-.005
Phase 3 Stand Variables						
Density	-.007	-.041	-.075	.020	.006	.007
Height	.118	.102	.145	.080	.050	.062
Origin	-.067	-.039	-.084	-.045	.009	.005
Site Class	.086	.091	.142	.064	.044	.040
Commercialism	-.010	-.045	-.095	.007	-.005	-.034

Adv - Advanced decay
Incip - Incipient decay
See Section 3.3 for decay definitions

TABLE 2

SIGNIFICANCE OF DEFECT LOCATION[1] BY EXTERNAL INDICATOR
SCHEFFE TEST RESULTS

External Defect	No. Observations	Actual Volume (m^3)		
		Adv	Adv+Incip	Adv+Incip+Stain
Discoloured Bark	10	n.s.[2]	n.s.	n.s.
Conks/Cankers	322	n.s.	n.s.	n.s.
Open Scars	68	n.s.	n.s.	n.s.
Branch Stubs	23	n.s.	n.s.	n.s.
Dead Foliage/Branches	18	n.s.	n.s.	n.s.
Old Broken Top	2	Too few cases to evaluate		
Conks/Branch Stubs	2	Too few cases to evaluate		
Conks/Dead Foliage	1	Too few cases to evaluate		
Scars/Branch Stubs	2	Too few cases to evaluate		
Discoloured Bark/Conks	9	Too few cases to evaluate		

[1]Locations Tallied: BOT - bottom third of tree only
MID - middle third of tree only
TOP - top third of tree only
ALL - entire tree
BOT/MID - bottom and middle sections only
MID/TOP - middle and top sections only
BOT/TOP - bottom and top sections only

[2]n.s. indicates no significant difference at .95
* indicates significant differences at .95

TABLE 3

SIGNIFICANCE OF DEFECT SEVERITY[1] BY EXTERNAL INDICATOR
SCHEFFE TEST RESULTS

External Defect	No. Observations	Actual Volume (m^3)		
		Adv	Adv+Incip	Adv+Incip+Stain
Discoloured Bark	10	n.s.[2]	low vs high[3]	n.s.
Conks/Cankers	322	n.s.	n.s.	n.s.
Open Scars	68	low vs severe[3]	low vs severe[3]	n.s.
Branch Stubs	23	n.s.	n.s.	n.s.
Dead Foliage/Branches	18	n.s.	n.s.	n.s.
Old Broken Top	2	Too few cases to evaluate		
Discoloured Bark/Conks	9	n.s.	n.s.	n.s.
Conks/Branch Stubs	2	Too few cases to evaluate		
Conks/Dead Foliage	1	Too few cases to evaluate		
Scars/Branch Stubs	2	Too few cases to evaluate		

[1]Severity Classes: Low
Moderate
High
Severe

[2]n.s. indicates no significant differences at .95
[3]See Section 5.3(c)

Figure 4a

Percent Total Decay by Species

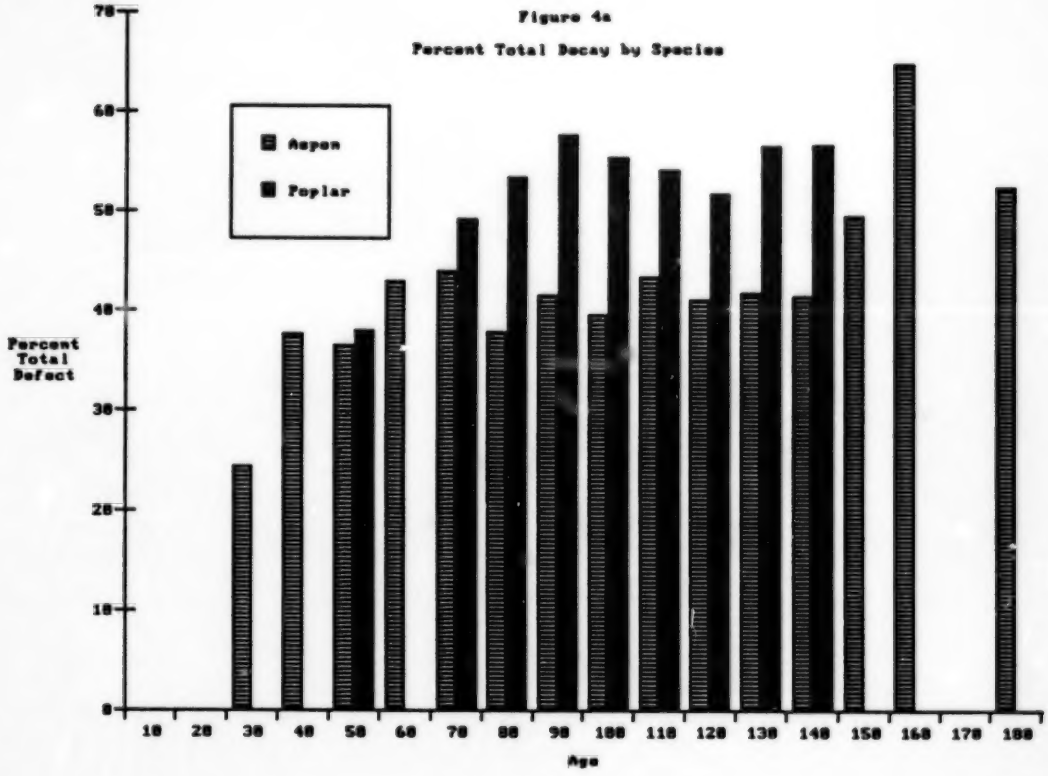


Figure 4b

Actual Decay Volume by Species

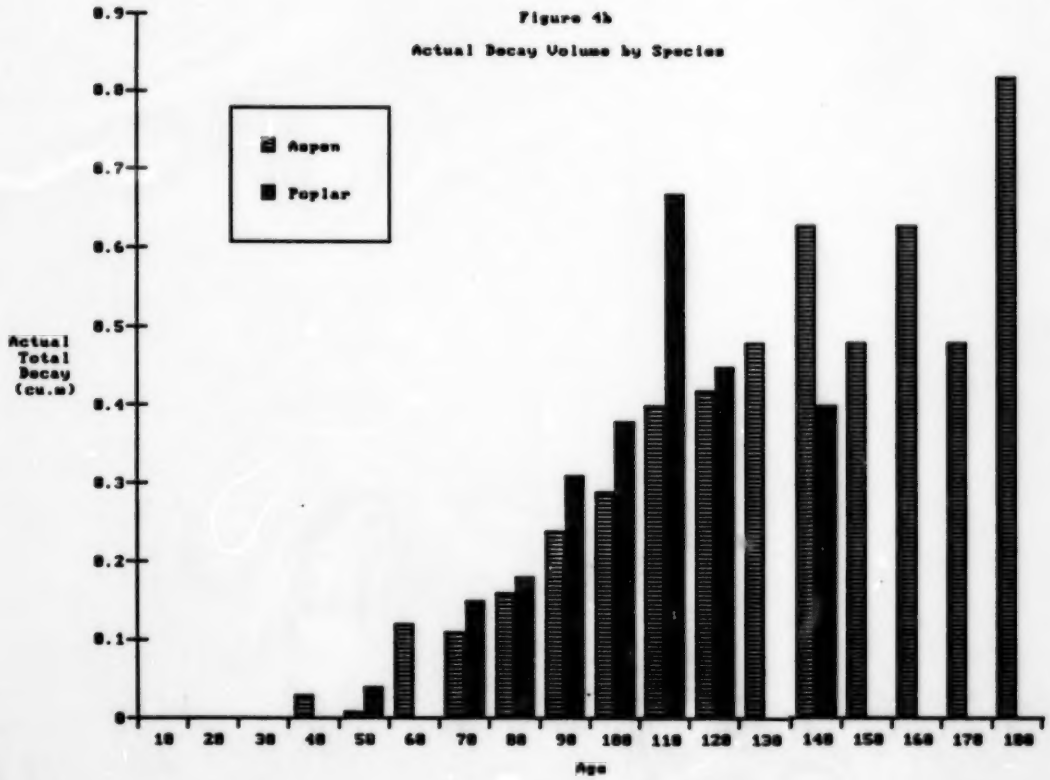


Figure 5a

Percent Decay by Cover Group

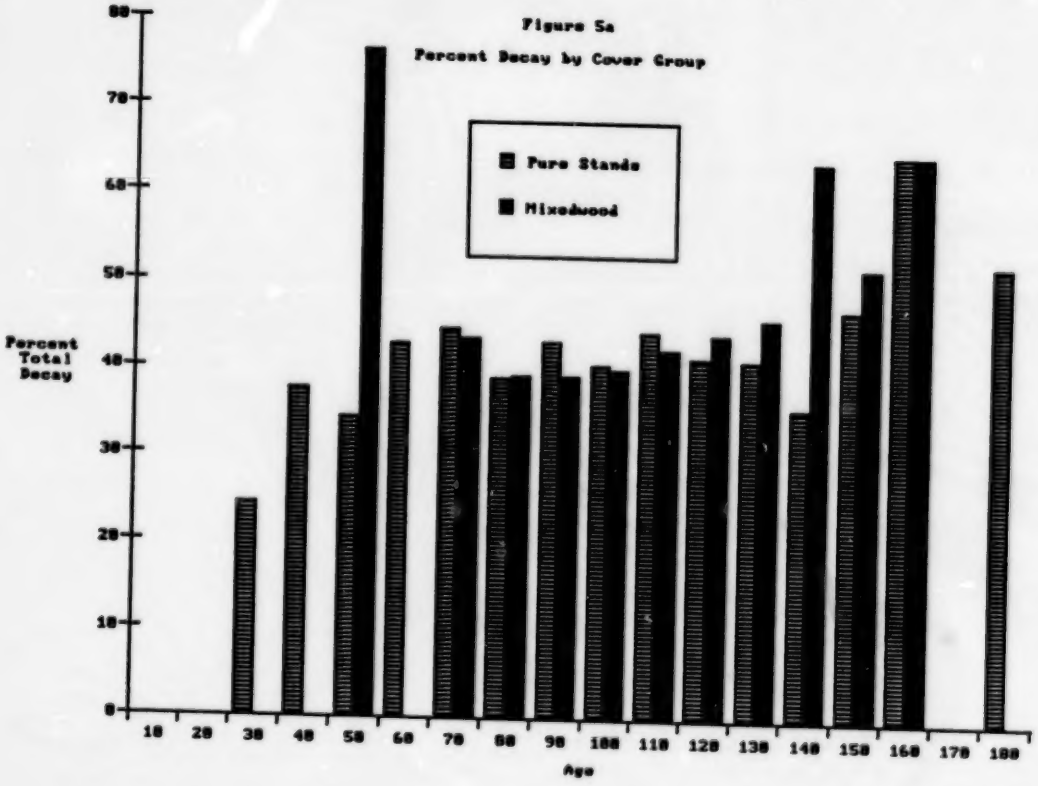
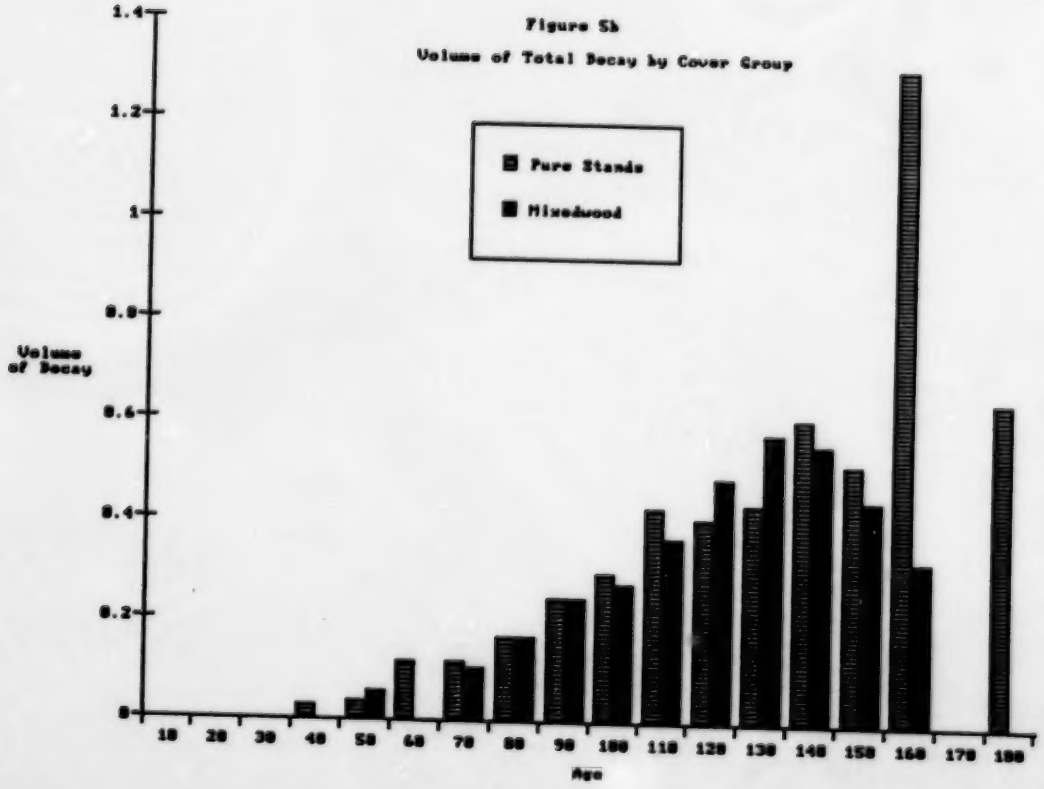


Figure 5b

Volume of Total Decay by Cover Group



4.3 External Decay Indicators

One of the purposes of this project was to record characteristics of external decay indicators including the type of defect, its location and extent or severity. Initial ANOVA tests showed that external decay indicator was a significant factor. However, under the more conservative Scheffe multiple comparison test, the only significant difference was the non-suspect class versus those trees with conks recorded. Both defect location and severity showed minor significant differences within each defect type (see Tables 2 and 3). Despite these seemingly significant differences, there are too few sample trees in each location or severity class to draw any conclusions.

The combined interaction of defect location and severity within external defect types could not be determined through ANOVA tests due to the numerous unsampled categories.

4.4 Regression Estimators

The correlation results and scatterplots of defect against numerous independent variables suggested a regression approach to estimate decay volumes.

For these tests, actual decay volume and decay percentage were used as dependent variables. Least squares regression analysis was performed on only a portion of the data set. Approximately 10% of the observations were retained for validation purposes. Variables were evaluated in a stepwise procedure. Results of this analysis are shown in Table 4.

The equations in Table 4 are a selection of the "best" equations produced by the analysis program considering the difficulty with which variables can be measured (e.g. site index, stump age) and the high correlation between certain independent variables (e.g DBH and DBH^2). Table 4 also includes appropriate statistics describing correlations, number of samples and standard errors. Paired t-tests were used to evaluate the predictive capability of each regression equation on the validation data set (see Table 5).

The most promising results were obtained estimating stain volume (Equations 3 and 6) and the sum of advanced+incipient+stain volume (Equations 5 and 7) from transformations of dbh and tree height. Because poor relationships existed for the prediction of incipient+advanced decay, an attempt was made to estimate the volume of incipient+advanced as the difference between the estimates of advanced+incipient+stain (Table 4, Equations 5 and 7) and stain alone (Table 4, Equation 3). This is represented by Equations 13 and 14 in Table 5.

TABLE 4

RESULTS OF REGRESSION ANALYSIS

Equation Number	Dependent Variable	Constant	Independent Variables* (with coefficients)	R^2	No.	S.E.M.+
1	Advanced Decay	-0.02376	+ .0U00910420 DBH^2	.148	645	.095 (164%)
2	Incipient Decay	+0.01689	+ .0000241969 DBH^2 - 000095387 P3AGE	.052	645	.046 (170%)
3	Stain	-0.22511	+ .000189916 DBH^2 + .01069 HT	.648	645	.077 (40%)
4	Advanced + Incipient	-0.01756	+ .00011433 DBH^2	.210	645	.097 (114%)
5	Advanced + Incipient + Stain	-0.28210	+ .00029706 DBH^2 + .01270 HT	.647	645	.114 (40%)
6	Natural log of Stain	-5.69303	+ 1.62869 DBH+0.12173 HT-.413 SI+.00906172 SI^2	.634	645	.486 (45%)
7	Natural log of Advanced + Incipient + Stain	-9.46867	+ 1.97599 LN(DBH) + 0.05833 HT	.673	645	.445 (48%)
8	Percent Advanced Decay	5.90427	+ 0.0032503 DBH^2	.011	645	12.546 (70%)
9	Percent Incipient Decay	8.02216	- 0.01668 P3AGE - 0.000015412 $STAGE^2$	.015	645	6.868 (150%)
10	Percent Stain	27.26297	+ 0.00023905 $STAGE^2$	.007	645	9.425 (32%)
11	Percent Advanced Incipient		No significant variables			
12	Percent Advanced + Incipient + Stain	39.95057	+ .0032586 DBH^2	.008	645	15.015 (35%)

*DBH = Diameter at breast height (cm outside bark)
HT = Total tree height in meters from ground to top of tree
P3AGE = Age of stand according to Phase 3 classification
SI = Site index of tree (total tree height at breast height age of 50 years)
STAGE = Age at stump (0.3 m above point of germination)
+S.E.M. = Standard error of the mean (standard error as a percent of the mean is in brackets)

TABLE 5

RESULTS OF PAIRED T - TESTS ON REGRESSION ESTIMATORS

Equation Number	Dependent Variable	Regression Equations*	'T' Value	Level of Sig	No. of Obs.
1	Advanced	$-0.02376 + .0000910420\ DBH^2$	-0.61	N.S.	99
2	Incipient	$+0.01689 + .0000241969\ DBH^2 - 000095387$ P3AGE	-0.05	N.S.	99
3	Stain	$-0.22511 + .000189916\ DBH^2 + .01069$ HT	-0.74	N.S.	99
4	Advanced + Incipient	$-0.01756 + .00011433\ DBH^2$	-0.58	N.S.	99
5	Advanced + Incipient + Stain	$-0.28210 + .00029706\ DBH^2 + .01270$ HT	-0.99	N.S.	99
7	Natural log of Advanced + Incipient + Stain	-9.46867 + 1.97599 LN(DBH) + 0.05833 HT	-2.49	***	99
13	Advanced + Incipient (5-3)	$-0.05699 + .000107144\ DBH^2 + .00201$ HT	-0.60	N.S.	99
14	Advanced + Incipient (7-3)	Exp. (-9.46967 + 1.97599 LN (DBH) + 0.05833) + 0.22511 - $0.000189916\ DBH^2$ - 0.01069HT	-2.53	***	99

*DBH = Diameter at breast height (cm outside bark)
HT = Total tree height in meters from ground to top of tree
P3AGE = Age of stand according to Phase 3 classification
SI = Site index of tree (total tree height at breast height age of 50 years)
Level of Sig. - N.S. - no significant difference at all levels (.95, .90 and .67)
*** - significant difference at all levels (.95, .90, and .67)

5 DISCUSSION

5.1 Forest Cover Descriptor

The results obtained in trying to relate decay volume estimation to the Phase 3 stand descriptor were very poor (see Table 1). These results were not unexpected because the covertype classification used in the Phase 3 inventory was too broad to account for any variation in decay estimates. Height classes are six metres wide and crown closure is recorded in 25% classes (approximately) (Anon. 1985a); however, the latter do not adequately reflect differences in stocking levels between stands. Interpreted age classes are in ten-year intervals, but experience has shown that these classes are rarely accurate on a stand-by-stand basis. Complicating the inventory specifications is the fact that pure hardwood types were not given the same emphasis regarding quality and ground-truthing as coniferous forest types. This resulted in lower interpretation accuracy in hardwood stands.

5.2 Stump Age

Stump age could prove useful in estimating some levels of decay, but would involve obtaining actual ages from sample trees which are often difficult to ascertain accurately as the summer and spring wood in such trees is not obviously different, as with conifers. Even if individual tree ages can be accurately determined, stand age is not as easily determined.

In this study, two-thirds of the sampled stands were found to contain more than one age class (the range of sample tree ages was greater than twenty years). Figures 6a and 6b clearly illustrate the variability of individual tree age using two estimates of stand age: (a) the average age of all sampled trees on the stand, and (b) the age based on the photo-interpreted origin. Evidently, stand history or a past disturbance has allowed uneven-aged, or multi-aged, aspen stands to develop.

Trees of the same dbh but different age classes within the same stand appear to have similar amounts of decay. Tree size (i.e. dbh) appears to be of greater value in estimating decay than age. In comparing these results with LeMay's 1985 report, it was observed that trees which were 40 years old in a 40-year-old stand have different volumes of decay than 40-year-old trees from a 100-year-old stand. However, within the 100-year-old stand, the decay in 40-year-old trees does not differ from the decay levels in 100-year-old trees. This suggests that we need to know more about a stand's history to explain the decay volumes observed. Age alone cannot explain these differences.

5.3 External Indicators

The poor results obtained in estimating decay from external decay indicators (refer to Tables 1, 2 and 3) may be the result of a number of factors:

Figure 6a

Range of Sample Tree Ages
With Average Stump Age of the Stand

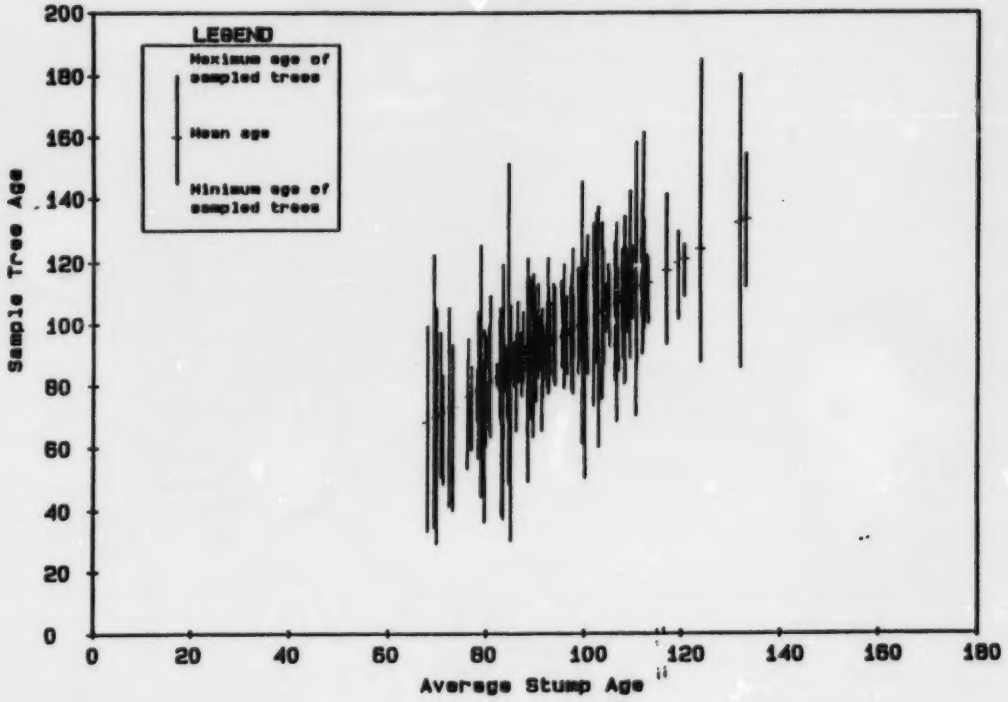
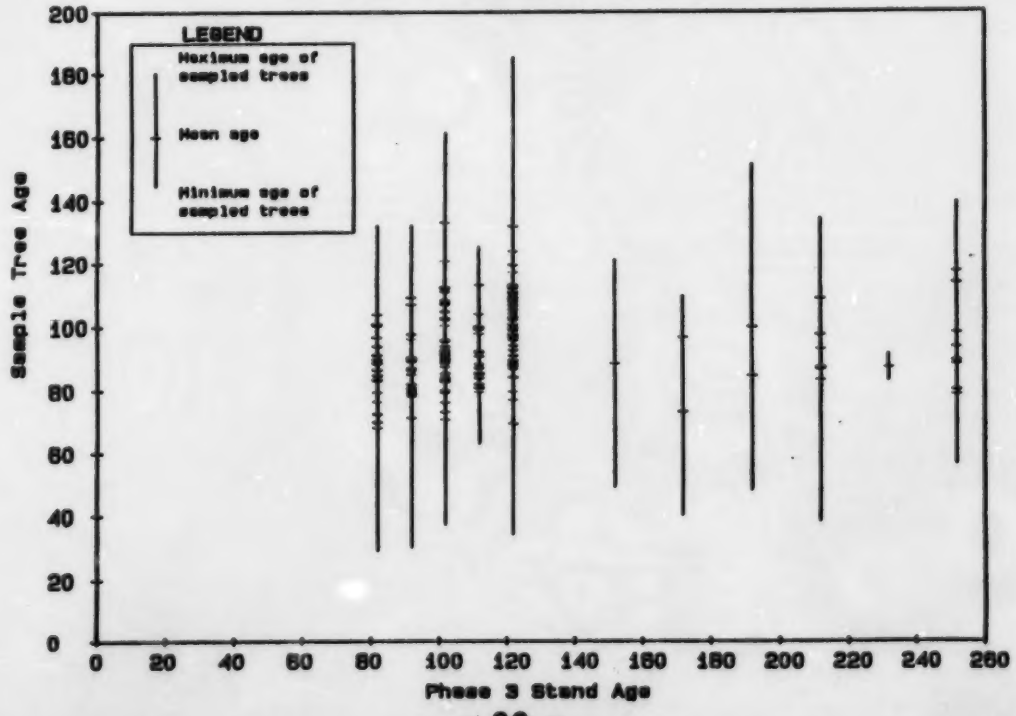


Figure 6b

Range of Sample Tree Ages
With Phase 3 Interpreted Stand Age



a) external indicators can only be used as useful indicators of decay presence or absence,

b) locations of defects may be difficult to record due to restricted visibility in taller trees or due to stand density, especially when sampling occurs during leaf-on conditions,

c) severity of internal defect is not indicated by external signs. While some significant differences were found in defect location (see Table 3), the consistency of the classification of severity is suspect. In all cases, the ranking of severity from LOW to MODERATE to HIGH and SEVERE was not obviously related to the decay volumes observed. HIGH or SEVERE rankings consistently showed lower decay levels than LOW or MODERATE rankings.

d) since sampling was restricted to overmature stands, trees with significant decay indicators may already have fallen down, and been replaced by younger trees with as yet undeveloped external decay indicators.

In past studies the number of visible conks appeared to be positively correlated to the defect volume. This was not found to be the case in this study possibly indicating that the development of the conk has more importance than numbers of conks, or that the true number of conks cannot be determined from a ground position for the reasons cited in point (b) above.

5.4 Regression Estimators

Discrete variables (height class, density class, cull suspect class, etc.) performed relatively poorly as decay estimaters. Decay prediction through regression appears promising although more field data are needed to quantify losses due to decay. Using this approach defect estimates could not be tied to the forest management inventory (i.e. the stand descriptor cannot be used to estimate defect volumes). However, in most operational forestry situations, cruising is done on a stratum or stand basis which could provide an excellent data base from which to derive decay estimates.

Regression equations were selected to predict defect volume using independent variables that are relatively reliable and easily measured. The following equations were tested:

$$\text{Advanced} = -0.02376 + .000091042(DBH^2)$$
$$\text{Advanced + Incipient} = -0.01756 + .00011433(DBH^2)$$
$$\text{Advanced + Incipient + Stain} = -0.28210 + .00029706(DBH^2) + 0.01270(HT)$$

Two procedures were used to verify the predicted cull estimates. First, paired t-tests were run on an independent data set. The results (Table 5) indicate that no significant differences were noted between observed and predicted volumes of advanced decay, advanced+incipient and advanced+incipient+stain decay.

Following this, the regression equations were plotted against the prediction of gross tree volume to ensure that the equations were compatible and did not overlap. Figure 7a shows the plotted results of the three decay prediction equations, as well as the function for gross merchantable tree volume. The equation to predict advanced+incipient+stain appears to behave oddly at diameters less than 16 cm. Further sampling of trees in this diameter class would help improve the predictive ability of this equation. The relationship of decay volume to total gross tree volume can also be expressed as a percent. This is shown in Figure 7b. Generally, advanced decay averages 7%; advanced + incipient 10%; and advanced + incipient + stain 39% of total gross tree volume.

Overall, this approach has resulted in a prediction system that is simple, feasible to use and compatible with current inventory and survey procedures. The selected equations included tree dbh and height as independent variables. Stump age was frequently included in the original regression analysis, but because of the problems in reliably obtaining Populus age and the amount of time necessary to age each tree, this variable was not considered.

While it is recognized that some of the relationships of the recommended variables to decay levels are very weak, they are statistically significant and show no evidence of extreme bias. More importantly, they provide a quantitative and objective estimate of tree decay.

5.5 Prediction of Stand Use Category

The regression equations (described in Section 5.4) to predict advanced cull, advanced+incipient and advanced+incipient+stain were built into a cruise compilation program. Gross and net volumes were then calculated on a tree, plot and stand basis from the data gathered in this study. The ratio of net stand volume to gross stand volume was used to classify the stands into potential "use" categories. Those categories were defined as:

Use	Definition
Pulp	less than 20% cull (advanced + incipient + stain)
Chips	20 - 50% cull (advanced + incipient + stain)
Recycle	> 50% cull (advanced + incipient + stain)

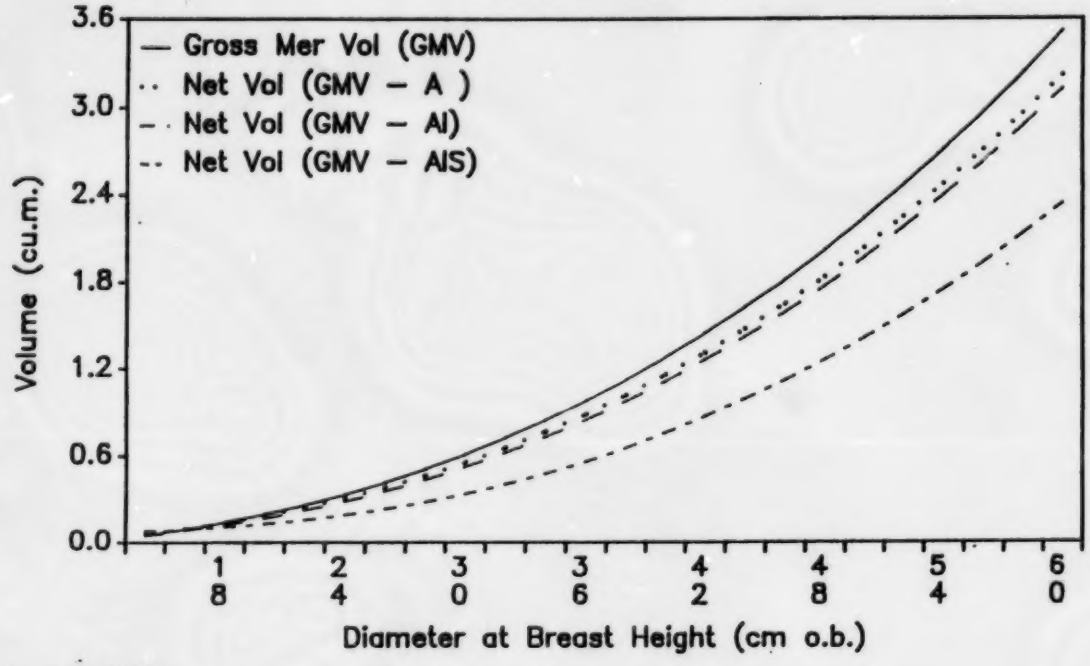
Based on this small sample size of 96 stands, the following results were obtained:

TABLE 6
Distribution of Stands by Use Category

USE CATEGORY	PERCENT CULL	NO. OF STANDS	PERCENT STANDS	FREQUENCY
	0 - 5	0	0	
Pulp	5 - 10	0	0	
	10 - 15	0	0	
	15 - 20	0	0	
	20 - 25	0	0	
	25 - 30	0	0	
Chips	30 - 35	2	2	
	35 - 40	16	17	
	40 - 45	77	80	
	45 - 50	1	1	
Re-cycle	50 +	0	0	
TOTALS		96	100	

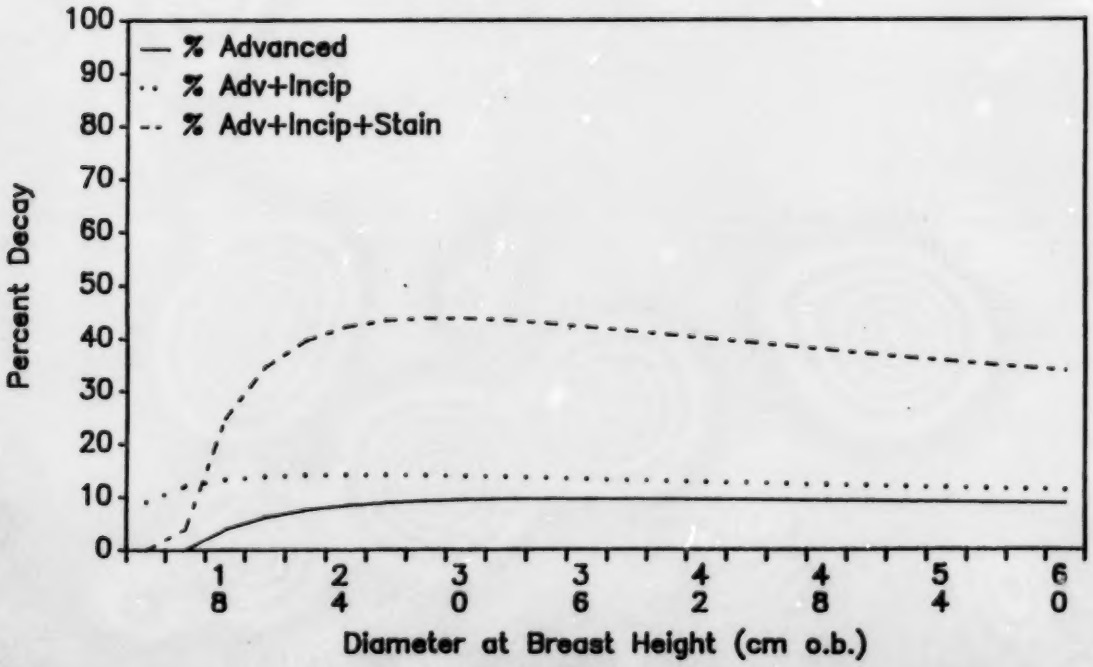
These results lead to the conclusion that the mature to overmature aspen stands sampled are generally merchantable for chip utilization. As displayed in Figure 7b, the obvious limiting factor for pulp utilization on these stands is the volume of stain. The stain component in this study consisted of both mineral and organic origins. In either case, there is no loss of volume to the processing facility, merely an added cost in bleaching out organic stains.

Figure 7a.
Gross and Net Merchantable Tree Volumes
at 15/11 Utilization



A – Advanced Defect
AI – Advanced + Incipient
AIS – Advanced + Incipient + Stain

Figure 7b.
Individual Tree Decay Percent
at 15/11 Utilization



6 CONCLUSION

One objective of this study was to evaluate the merchantability of overmature aspen stands in terms of their potential product use. Another was to search for a "break-up" age, beyond which no merchantable products could be derived. Progress has been made in defining stand merchantability, although no apparent "break-up" age was evident.

The use of Phase 3 Inventory origin classes as the sole predictor of decay is not recommended for a number of reasons:

1) the Phase 3 Inventory generally contains unreliable age estimates on a stand basis,

2) older aspen stands are frequently "uneven-aged" or "multi-aged",

3) field measured ages are not well correlated to photo-interpreted ages, in addition to the difficulty of measuring individual tree ages from cores or sections.

Estimation of stand cull and merchantability may have to occur during operational cruising assessments. Use of regression equations such as those derived here will provide a more accurate, objective and quantitative assessment of stand assessment prior to harvest.

7 LITERATURE CITED

Anonymous, 1985a Alberta Phase 3 Forest Inventory: Forest Cover Type Specifications. Government of Alberta. ENR Report No. Dept. 58.

Anonymous, 1985b Alberta Phase 3 Forest Inventory: An Overview. Government of Alberta. ENR Report No. I/86.

Anonymous, 1986. Alberta Phase 3 Forest Inventory: Tree Sectioning Manual. Government of Alberta. ENR Report No. Dept. 56.

Rowe, J.S. 1972. Forest regions of Canada. Publication 1300. Can. Dept. of Envir. Can. For. Serv. Ottawa.

APPENDIX 1

Description of External Decay Indicators

EXTERNAL VISUAL DECAY INDICATORS

TYPE OF DEFECT:

00 Non Suspect
01 Discoloration - Orange or Black bark
02 Conk & Cankers
03 Scars - Exposed Wood
04 Branch Stubs
05 Dead Foilage +/or Branches
06 Old Broken Tops

DEFECT LOCATION:

00 None
01 Bottom 1/3
02 Middle 1/3
03 Top 1/3
04 Full Tree
* When defect exists in more than one section drop the zero and amalgamate.
i.e. 13 Bottom 3rd - Top 3rd

DEFECT SEVERITY:

00 None
01 Low
02 Moderate
03 High
04 Severe

DEFECT SEVERITY FOR CONK & CANKERS, BRANCH STUBS

1 or 2 low
3 to 6 Moderate
6 to 8 High
9+ Severe

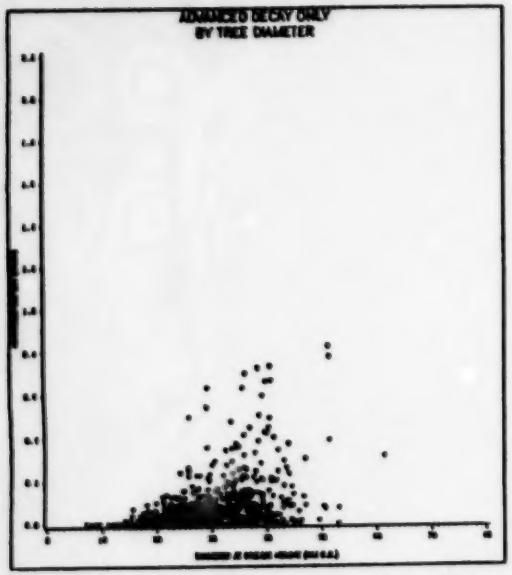
These are presently the only defects which the severity is based on actual numerical occurences.

DEVELOPMENTAL STAGE CLASS FOR CLASS FOR CONKS, CANKERS AND BRANCH STUBS

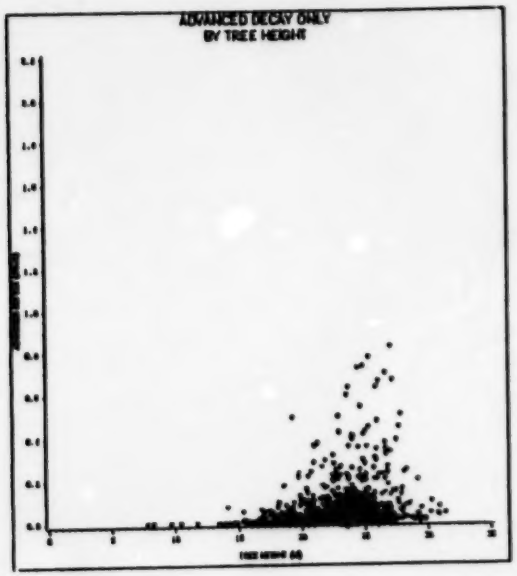
1. poorly developed, young, small
2. moderately developed, medium size
3. heavily developed, large, old

APPENDIX 2

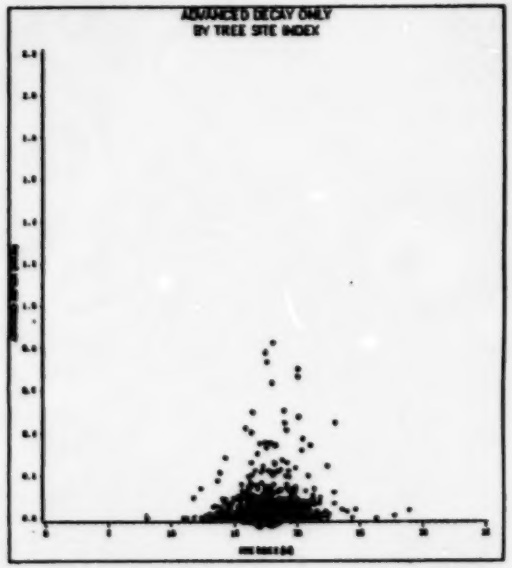
Scatterplots of Advanced Defect and Advanced and Incipient Decay



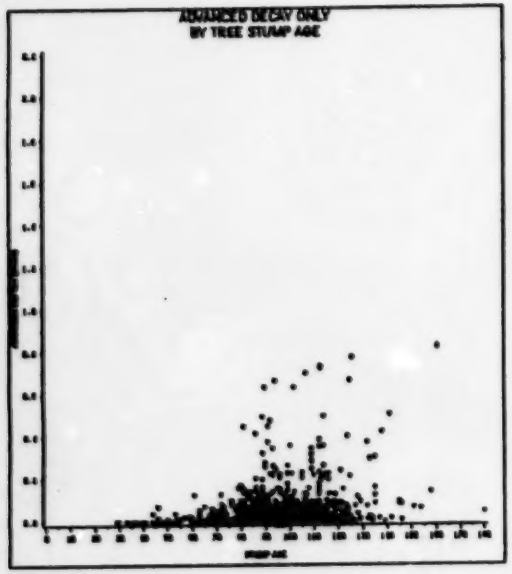
a) Tree diameter at breast height (cm o.b.)



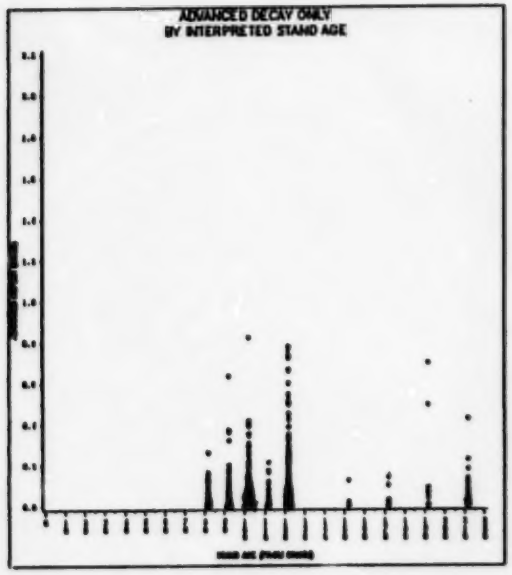
b) Tree height (m)



c) Tree site index (m. at 50 years b.h. age)



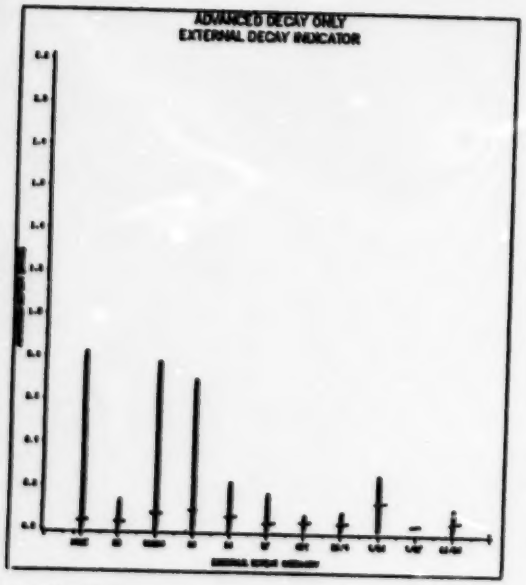
d) Tree stump age (years)



e) Photointerpreted stand age (10 year classes)

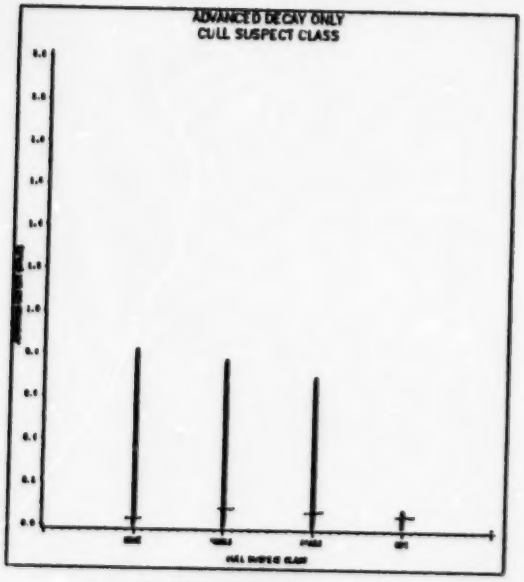
Appendix 2
Figure 1

Scatterplots of Advanced Defect



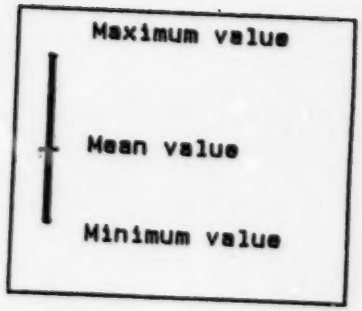
f) External decay indicator

NONE - No indicator
DB - Discolored Bark
CONKS - Conks or cankers
OS - Open scar
BS - Branch stubs
DF - Dead foliage
OBT - Old broken top
DB/C - Discolored bark/Conks
C/BS - Conks/Branch stubs
C/DF - Conks/Dead foliage
OS/DF - Open scars/Dead foliage



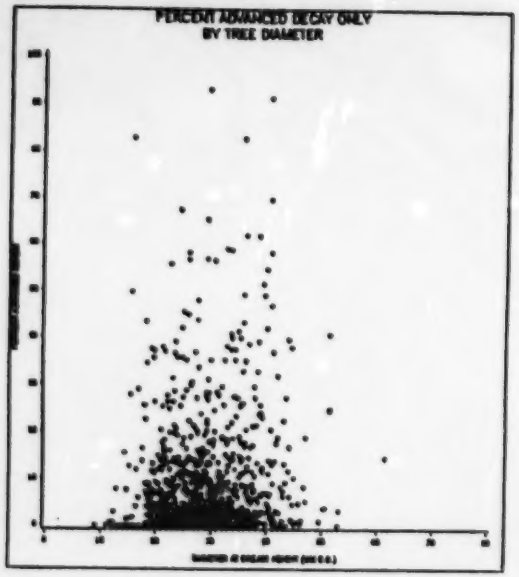
g) Cull suspect class

NONE - No indicator
CONKS - Conks or cankers
SCARS - Open scars
OBT - Old broken top

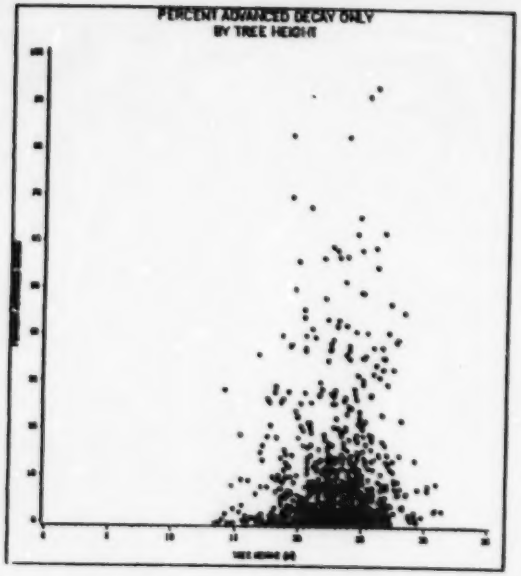


Appendix 2
Figure 1 cont'd

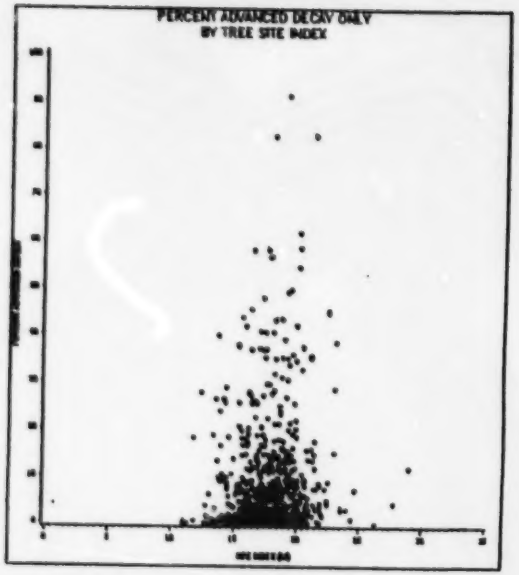
Scatterplots of
Advanced Defect



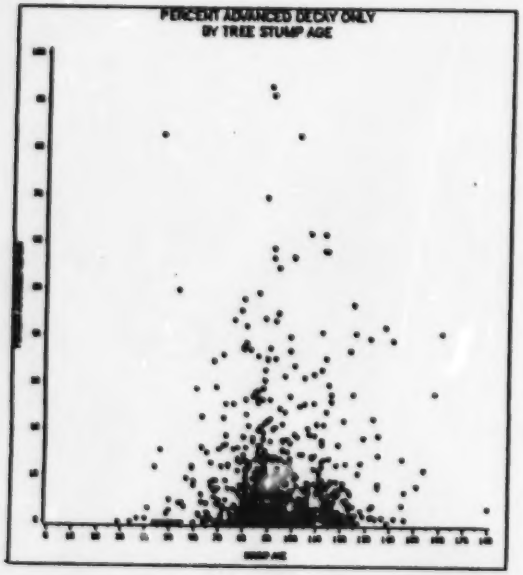
a) Tree diameter at breast height (cm o.b.)



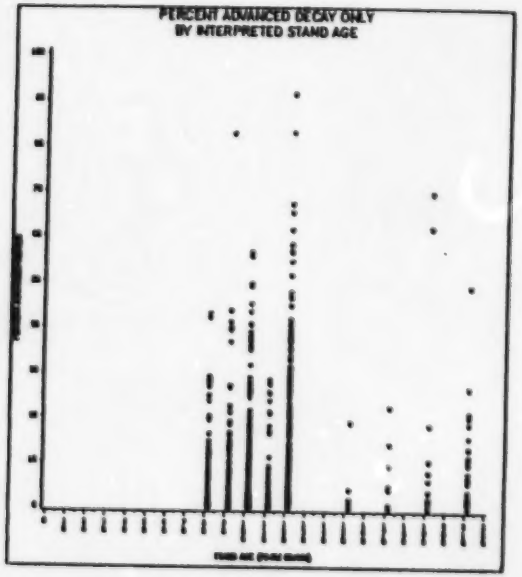
b) Tree height (m)



c) Tree site index (m. at 50 years b.h. age)



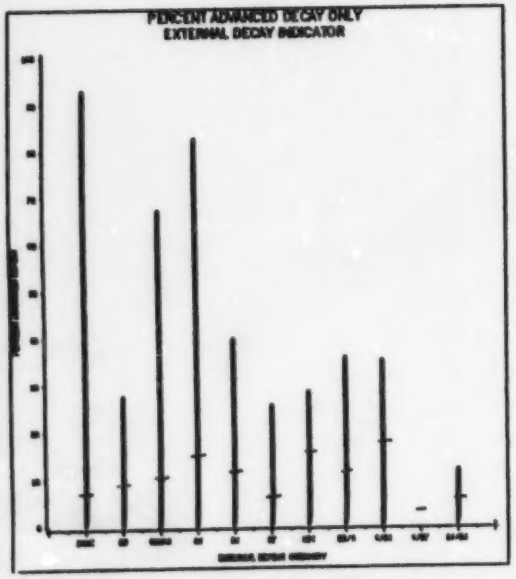
d) Tree stump age (years)



e) Photointerpreted stand age (10 year classes)

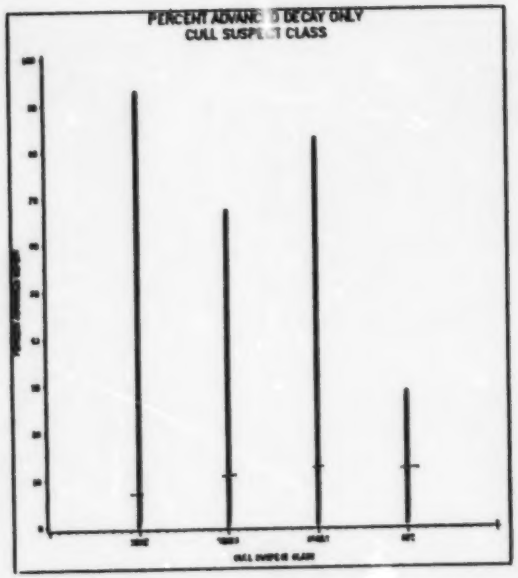
Appendix 2
Figure 2

Scatterplots of Percent Advanced Defect



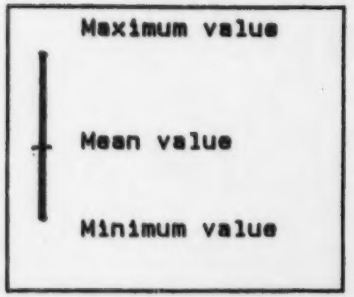
f) External decay indicator

NONE - No indicator
DB - Discolored Bark
CONKS - Conks or cankers
OS - Open scar
BS - Branch stubs
DF - Dead foliage
OBT - Old broken top
DB/C - Discolored bark/Conks
C/BS - Conks/Branch stubs
C/DF - Conks/Dead foliage
OS/DF - Open scars/Dead foliage



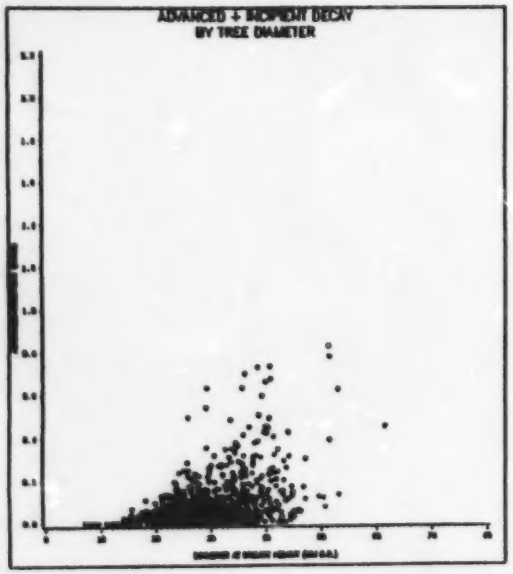
g) Cull suspect class

NONE - No indicator
CONKS - Conks or cankers
SCARS - Open scars
OBT - Old broken top

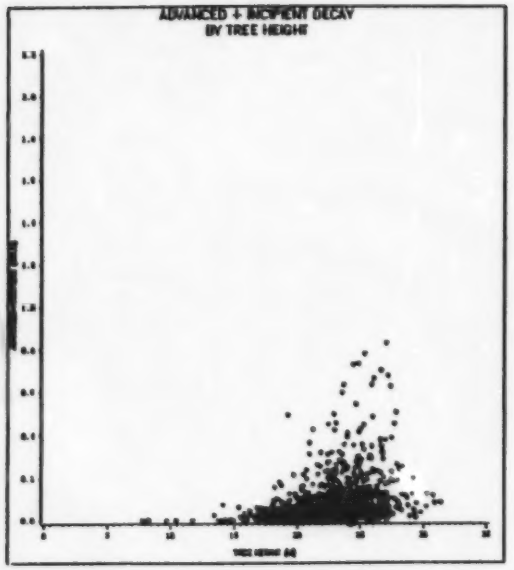


Appendix 2
Figure 2 cont'd

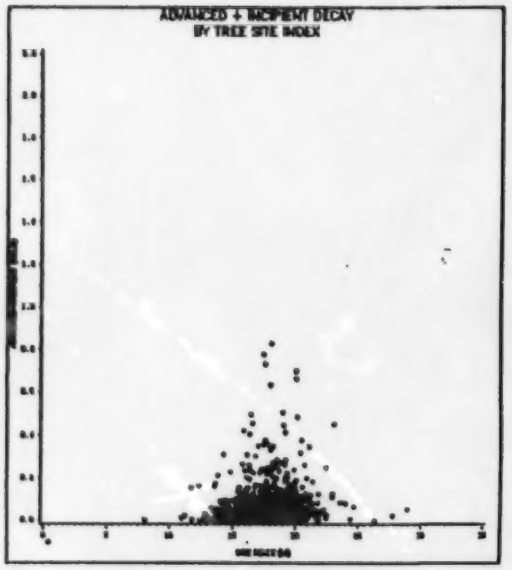
Scatterplots of
Percent Advanced Defect



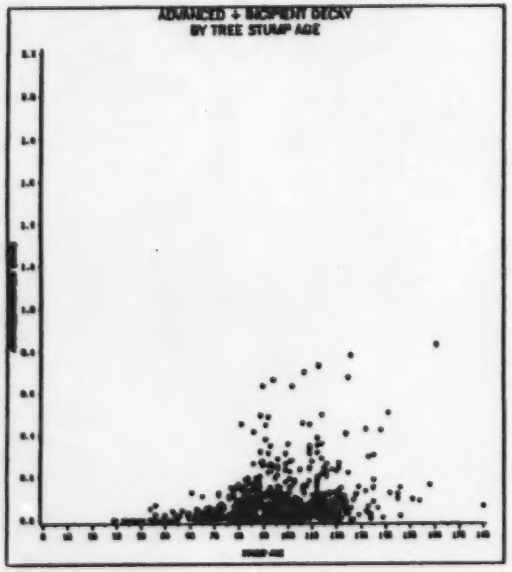
a) Tree diameter at breast height (cm o.b.)



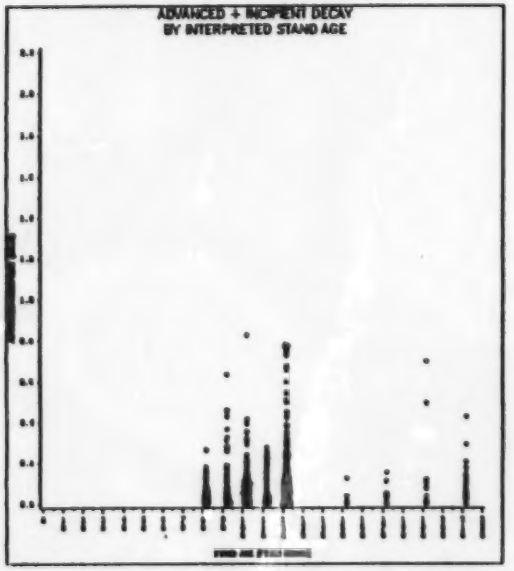
b) Tree height (m)



c) Tree site index (m. at 50 years b.h. age)



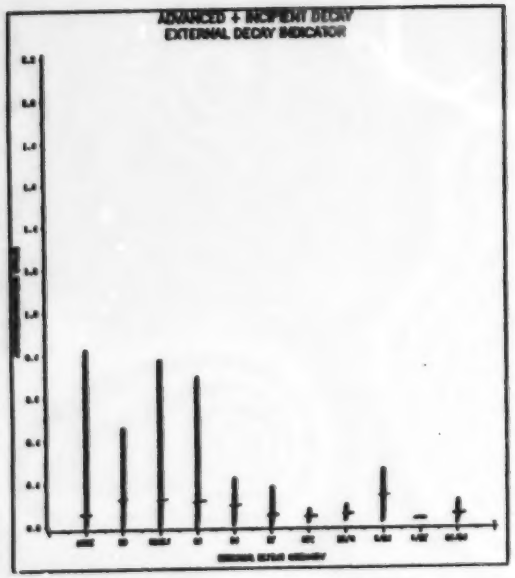
d) Tree stump age (years)



e) Photointerpreted stand age (10 year classes)

Appendix 2
Figure 3

Scatterplots of
Advanced+Incipient Defect



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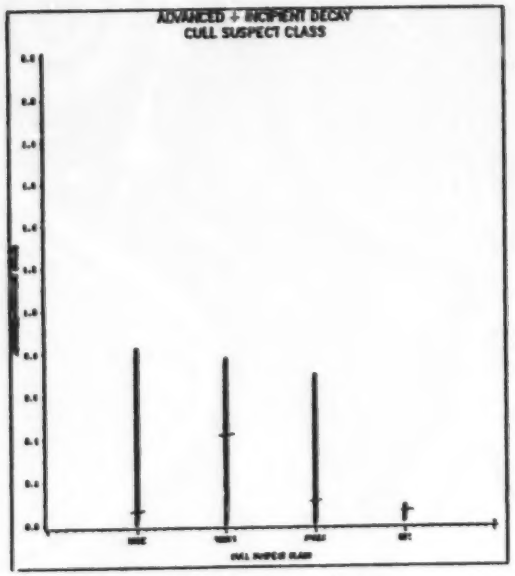

g) Cull suspect class

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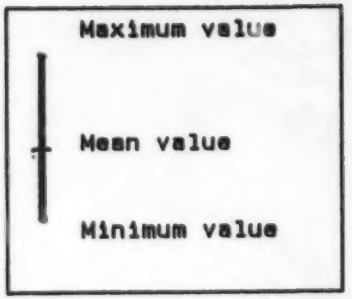
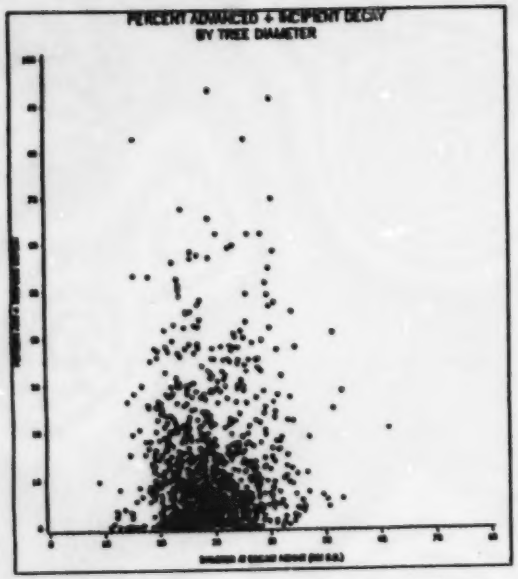
CONKS - Conks or cankers
SCARS - Open scars
OBT - Old broken top

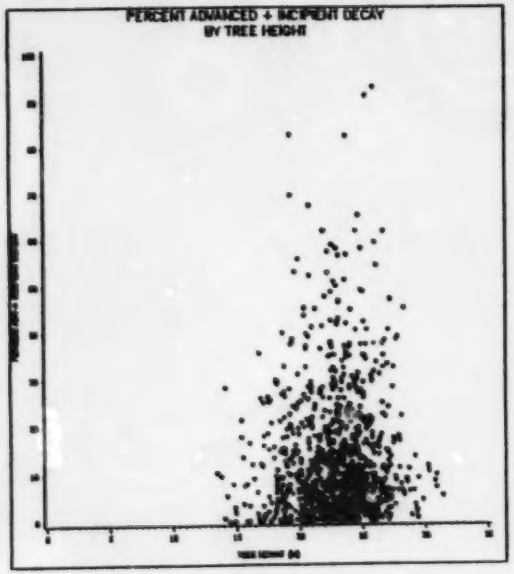


Appendix 2
Figure 3 cont'd

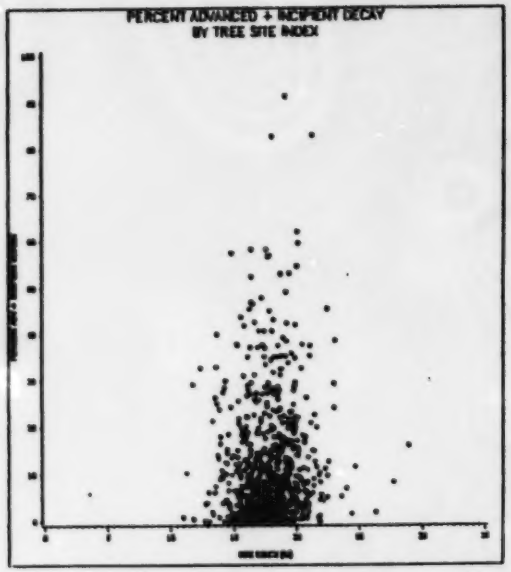
Scatterplots of
Advanced+Incipient Defect



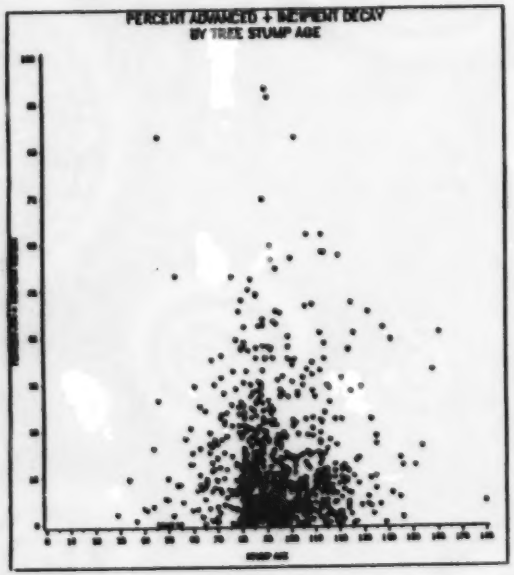
a) Tree diameter at breast height (cm o.b.)



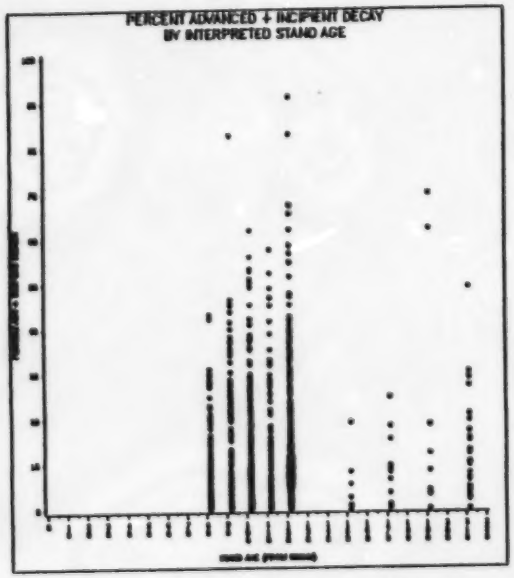
b) Tree height (m)



c) Tree site index (m. at 50 years b.h. age)



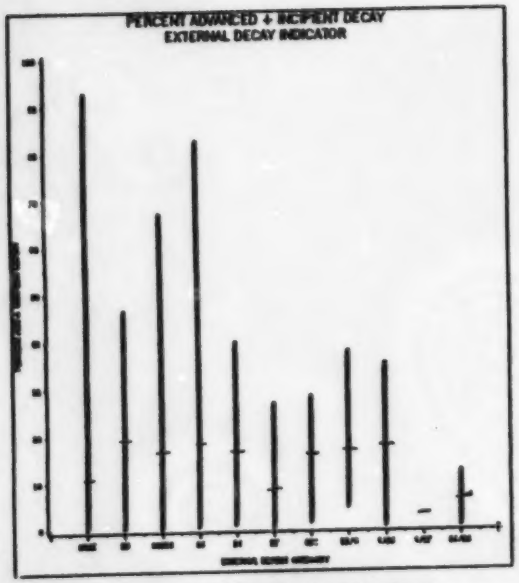
d) Tree stump age (years)



e) Photointerpreted stand age (10 year classes)

Appendix 2
Figure 4

Scatterplots of
Percent Advanced+Incipient Defect



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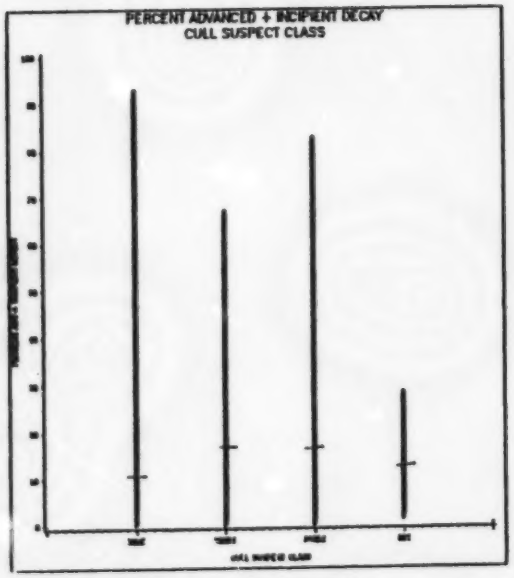

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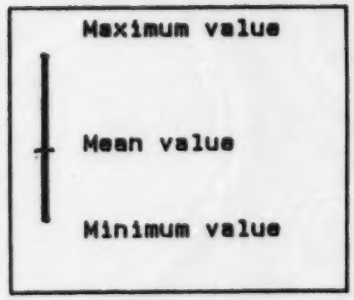

Appendix 2
Figure 4 cont'd

Scatterplots of
Percent Advanced+Incipient Defect